Chapter 5: Hurricanes & Coastal Storms

Since 1965, eleven of the thirteen events that prompted Presidential disaster declarations have been associated with tropical cyclones and coastal storms (Table 5-1). One declaration was for fire hazard and one was for a severe cold spell that affected South Florida.

Table 5-1. Presidential Disaster Declarations (1965-2004)

DR#	Date of Declaration	Event	Type of Assistance Provided*
209	09/14/1965	Hurricane Betsy	IA,PA-ABCDEFG
337	06/24/1972	Tropical Storm Agnes	IA,PA-ABCDEFG
955	08/24/1992	Hurricane Andrew	IA,PA-ABCDEFG
982	03/22/1993	Tornadoes, Flooding, High Winds & Tides, Freezing	IA,PA-ABCDEFG
1204	02/20/1998	Severe Storms, High Winds, Tornadoes & Flooding	IA,PA-ABCDEFG
1223	06/19/1998	Extreme Fire Hazard	PA-ABCDEFG
1249	09/28/1998	Hurricane Georges	IA,PA-ABCDEFG
1259	11/06/1998	Tropical Storm Mitch	IA,PA-ABCDEFG
1306	10/22/1999	Hurricane Irene	IA,PA
1345	10/04/2000	Severe Storms & Flooding	IA
1359	02/06/2002	Severe Winter Storm	Disaster unemployment
1539	08/11-30/2004	Tropical Storm Bonnie & Hurricane Charlie	IA
1551	09/13/2004	Hurricane Ivan	PA-B

* IA = Individual Assistance; PA = Public Assistance (and categories)

5.1 Defining the Hazard

The most significant hazards that could affect Monroe County are winds and flooding associated with tropical cyclones (hurricanes, tropical storms, and tropical depressions) and non-tropical coastal storms. Non-tropical coastal storms are less common, although such storms can be produce high winds and flooding rains.

The Monroe County *Comprehensive Emergency Management Plan* states that "the Florida Keys has one of the highest probabilities of being affected by tropical cyclones in the Continental United States," a characterization that is echoed by the National Hurricane Center.

Most of Monroe County has natural elevations of about 4 to 7 feet above mean sea level. This makes the area vulnerable to coastal flooding. The flatness of the topography means that heavy rainfall may accumulate due to slow runoff.

Hurricanes and tropical storms, as well as tropical depressions, are all tropical cyclones defined by the National Weather Service, National Hurricane Center, as warm-core non-frontal synoptic-scale cyclones, originating over tropical or subtropical waters, with organized deep convection and closed surface wind circulation about a well-defined center. Once they have formed, tropical cyclones maintain themselves by extracting heat energy from the ocean at high temperatures and releasing heat at the low temperatures of the upper troposphere. Hurricanes and tropical storms bring heavy rainfalls, storm surge, and high winds, all of which can cause significant damage. These storms can last for several days, and therefore have the potential to cause sustained flooding, high wind, and erosion conditions.

Tropical cyclones are classified using the Saffir-Sampson Hurricane Scale (Table 5-2) which rates the intensity of storms based on wind speed and barometric pressure measurements. The scale is used to predict potential property damage and flooding levels from imminent storms. Actual impacts are influenced by many variables that are not accounted for in this summary, such as the influence of the tidal cycle.

"A hurricane is when the wind blows so hard, the ocean gets up on its hind legs and walks right across the land."

from the movie "Key Largo"

Table 5-2. Saffir-Sampson Scale and Typical Damages

Category	Sustained Wind Speeds (mph)	Surge (ft)	Pressure (mb)	Typical Damage
Tropical Depression	<39	--	--	
Tropical Storm	39-73	3-5	--	Trees/foliage, unanchored mobile homes, signs, flooding on barrier islands/coastal roads, minor pier damage, small craft torn from moorings.
Hurricane 1	74-95	4-5	> 980	*Minimal* – Damage is done primarily to shrubbery and trees, unanchored manufactured homes are damaged, some signs are damaged, no real damage is done to structures on permanent foundations.
Hurricane 2	96-110	6-8	965-980	*Moderate* – Some trees are toppled, some roof coverings are damaged, and major damage is done to manufactured homes.

Table 5-2. Saffir-Sampson Scale and Typical Damages

Category	Sustained Wind Speeds (mph)	Surge (ft)	Pressure (mb)	Typical Damage
Hurricane 3	111-130	9-12	945-965	*Extensive Damage* – Large trees are toppled, some structural damage is done to roofs, manufactured homes are destroyed, and structural damage is done to small homes and utility buildings.
Hurricane 4	131-155	13-18	920-945	*Extreme Damage* – Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail' some curtain walls fail.
Hurricane 5	> 155	> 18	< 920	*Catastrophic Damage* – Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, some buildings fail completely.

Storm surge is a large dome of water which may be 50- to 100-miles wide and rising from less than 4-feet to over 18-feet high. Generally, surges begin to arrive before a storm's landfall, although the timing is influenced by the path, forward speed, and timing of each storm with respect to the tide cycle. Wind-driven waves are a significant component of tropical cyclones. The height of waves is influenced by storm characteristics and whether shorelines are buffered by barrier islands.

Storm surge can be modeled by various techniques; one such technique is the use of the National Weather Services' Sea, Lake and Overland Surges from Hurricanes (SLOSH) model. The model is used to predict storm surge heights based on hurricane category. Surge inundation areas are classified based on the category of hurricane that would cause flooding. As the category of the storm increases, more land area will become inundated. Storm surge is a major component of Nor'easter storms along the East Coast of the U.S. Because winds are moving from a north and/or eastward position, winds move across the ocean towards shore and form large waves.

5.1.1 Flood Insurance Rate Maps

The National Flood Insurance Program (NFIP) prepares maps to depict areas that are predicted to flood during events up to and including the 1-percent annual chance flood (commonly called the 100-year flood). In Monroe County, virtually all areas shown on the Flood Insurance Rate Maps (FIRMs) are impacted by coastal flooding, whether due to

hurricanes or other coastal storms. Monroe County and the cities all maintain copies of their current effective FIRMs and the maps are available for inspection by the public.

In order to make federal flood insurance available to citizens, communities adopt FIRMs and administer floodplain management ordinances. Table 5-3 indicates when the County and cities first joined the NFIP and the date of the current map. Monroe County and the cities were among the first to have maps revised and updated into the Geographic Information System format under FEMA's Map Modernization initiative. FEMA's Multi-Year Flood Hazard Identification Plan (MHIP) indicates that funding for the Monroe County FIRMs was provided prior to Fiscal Year 2004.

Table 5-3. Flood Insurance Rate Maps

	Joined the NFIP	Date of Current Map
Monroe County	June 15, 1973	February 18, 2005
Islamorada	October 1, 1998	February 18, 2005
Key Colony Beach	July 16, 1971	February 18, 2005
Key West	September 3, 1971	February 18, 2005
Layton	July 13, 1971	February 18, 2005
Marathon	October 16, 2000	February 18, 2005

5.2 Hurricane Effects in Monroe County

Hurricane modeling prepared for South Florida predicts surge depths for different categories as a function of track path. Some paths are predicted to producer higher surges than others. Throughout Monroe County, most locations will experience surges of 9-feet or more as a result of category 3, 4 and 5 hurricanes (Table 5-4). Chapters 8 through 12 include tables detailing maximum predicted water depths above mean seal level in Key West, Key Colony Beach, Layton, Marathon, and Islamorada.

Table 5-4. Probably Storm Tide Ranges*

	Elevation (above MSL)	
Saffir-Simpson	Monroe	Dade
Category 1	5	5
Category 2	7	7
Category 3	10	10
Category 4	13	13
Category 5	+15	+15

* Lower Southeast Florida Hurricane Evacuation Study (1983)

Assigning frequencies to hurricanes is difficult, in large part because of the relatively short record. Based on past storms, it appears that the frequency for a Category 5 storm in Key West is one every 36 years (or about 3-percent chance in any given year – by comparison, the "100-year" storm has a 1-percent chance of occurring in any given year). A Category 4 storm is likely to occur about once every 22 years (or about 5-percent in any given year). Category 3, 2, and 1 hurricanes and tropical storms have increasing probabilities of occurrence in any given year. Overall, Monroe County has been advised that in any given year, there is a one in four chance (25-percent) that the area will be affected by a tropical cyclone of some intensity.

One of the greatest threats posed by hurricanes is their erratic and irregular tracks, making prediction of landfall difficult. Between 1886 and 2004, 47 tropical cyclones of hurricane intensity have passed within 125 miles of Marathon, in the Middle Keys, with an average of one storm every 2.5 years. Hurricanes are most common in September and October, although they have occurred in all months of hurricane season.

5.3 Some Major Hurricanes

The Florida Keys have experienced many hurricanes and tropical storms – too many to list. Brief descriptions of some or the more significant storms (Table 5-5) are sufficient to characterize the hurricane history of the area.

Table 5-5. Some Major Hurricanes that Affected Monroe County

1919 Hurricane (September 2-15). The hurricane passed Key West and the Dry Tortugas on a westward course. Key West recorded winds of 95 mph, with a barometric pressure of 28.81 inches. Water levels were 5-7 feet above Mean Sea Level (MSL)
1929 Hurricane (September 22 to October 4). The hurricane crossed over Key Largo on a northerly course. Key Largo reported winds estimated at over 100 mph, a central barometric pressure of 28 inches, and tide levels of 8-9 feet above MSL. Key West experienced tide levels of 5-6 feet above MSL and winds of 66 mph.
1935 Hurricane (August 29-September 10). The small, extremely violent, Category 5 hurricane crossed the Florida Keys on a northwesterly track. The Tavernier-Islamorada area reported winds estimated at 120 mph with gusts from 190-210 mph. Tide levels ranged from 14 feet above MSL in Key Largo to 18 feet above MSL in Lower Matecumbe Key. The storm was so intense and tightly wrapped that Key West had tide levels of only 2 feet above MSL and average sustained winds of less than 40 mph. Tragically, the storm caused the death of many WWI veterans who were working on construction of Henry Flagler's Overseas Railroad. The 1935 Keys Hurricane remains the strongest storm ever to hit the Continental U.S.
Hurricane Donna, 1960 (August 29-September 19). Hurricane Donna curved northwestward over the Middle Keys near Long Key/Layton and then traveled northward toward the Gulf Coast towns of Naples and Fort Myers. Areas in the vicinity of the storm experienced winds speed of 128 mph and a central pressure of 28.44 inches. The storm affected the Everglades with estimated winds of 150 mph. Tide levels were reported at Upper Matecumbe Key of 13.5 feet above MSL, at Plantation Key 10+ feet above MSL, and 8.9 feet above MSL in Key Largo. As of 1992 Hurricane Donna, a Category 4 storm, was listed as the 6th most intense hurricane in the U.S.

Table 5-5. Some Major Hurricanes that Affected Monroe County

Hurricane Betsy, 1965 (August 26-Septmber 12). Hurricane Betsy passed over Marathon while moving westward into the Gulf of Mexico. The lowest central pressure was measured in Tavernier at 28.12 inches and wind speeds were estimated to be 120 mph. Tide levels in Tavernier were 7.7 feet above MSL and Key Largo had tide levels of around 9 feet above MSL.
Hurricane Andrew, 1992. This storm made landfall in southern Dade and northern Monroe Counties in the early morning hours of Monday, August 24, 1992. A strong Category 4, the storm severely affected Monroe County in the Key Largo area, particularly North Key Largo and the community of Ocean Reef. According to National Hurricane Center, maximum sustained winds for this storm were 145 miles per hour, with gusts to 175 miles per hour. At landfall, its central barometric pressure was, 926 Mb, is the third lowest in the 20th Century. At the time, Hurricane Andrew was the third strongest storm this Century. Storm tides at Ocean Reef have been estimated at about 4.5 feet on the bay side and 3.9 to 5.0 feet on the ocean side. Because of the storm's intensity and tight configuration, it quickly moved inland. Hurricane Andrew was costly for Monroe County, including extensive roof and other structural damage to residences; public safety and administrative buildings; the Card Sound Road toll facility; and resort buildings; loss of emergency equipment; severe damage to roadways and signs; loss or emergency and security vehicles; and damage to marinas and craft. Other expenses accrued from large-scale landscape loss and damage; loss of and damage to private vehicles; damage to recreational facilities; and great loss of personal property. Many businesses in Upper Key Largo experienced some damage (especially roofs) and loss of signs and landscaping. County roadways were blocked by debris and street and road signs were lost. The Florida Keys Electric Coop reported $130,000 in losses of utility poles and related infrastructure. Total damage in Monroe County exceeded $131,000,000.
Hurricane Georges, 1998. On September 25, 1998, this hurricane made landfall in the Lower Keys and affected the entire county to some extent. Hurricane Georges devastated the Caribbean, including Haiti and the Dominican Republic, Puerto Rico, and Cuba before taking aim at Monroe County. When it hit Santo Domingo in the Dominican Republic on September 22nd, it was a strong Category 3 with sustained winds of120 mph. It weakened to a Category 2 by the time it arrived in the Florida Keys, with maximum sustained winds of 92 mph measured at the Naval Air Station (Boca Chica) near Key West. Gusts of 110 mph were reported in Marathon. According to the Key West Weather Service, precipitation levels in the Lower Keys were identified as 8.65 inches on the south side of Sugarloaf Key, 8.38 inches at Key West International Airport, 8.20 inches on Cudjoe Key, and 8.4 inches at Tavernier in the Upper Keys. The most severe damage was sustained between Sugarloaf Key and Big Pine Key in the Lower Keys. Damage estimates, including insurable, uninsurable, and infrastructure loss, was nearly $300 million. Substantial damage occurred to mobile homes and landscaping throughout the keys. Roof and flood damage occurred in several areas including Big Coppitt, Sugarloaf, Summerland, Ramrod, and Big Pine in the Lower Keys. Similar damage affected the Middle Keys including Marathon, Key Colony Beach, Grassy Key, Long Key/Layton, and Duck Key. In the Upper Keys, several hotels and motels, such as the Cheeca Lodge received damage as did portions of roadway, e.g. Lower Matecumbe where overwash occurred. A school under construction in Sugarloaf Key sustained damage to the unfinished roof, heavy damage to the Big Pine Community Center, and damage to the air conditioning unit on the roof of Marathon High School, which resulted in interior water damage. The City of Key West sustained damage to private buildings and public property, especially along low-lying areas along South Roosevelt Boulevard.
Tropical Storm Mitch, 1998. Arriving on November 4 and 5, Mitch initially was forecast to bring minimal tropical storm conditions to the Keys. Unfortunately, feeder bands from Mitch containing super cells spawned several damaging tornadoes in the Upper Keys. Sections with mobile homes were especially hard hit. Islamorada experienced an F-1 tornado. Rock Harbor and Key Largo were hit by F-2 tornadoes. The State reported Monroe County's damages were estimated at nearly $11 million.

5.4 Losses Due to Major Disasters

No definitive record exists of all losses – public and private – due to disasters for Monroe County. For the United States as a whole, estimates of the total public and private costs of natural hazards range from $2 billion to over $6 billion per year. Most of those costs can only be estimated. In most declared major disasters, the Federal government reimburses 75% of the costs of cleanup and recovery, with the remaining 25% covered by states and affected local jurisdictions. FEMA reimburses expenditures those associated with:

- Public assistance for certain categories of damage/expenditures: debris removal, emergency services, roads and bridges, flood control facilities, public buildings and equipment, public utilities, and parks and recreational facilities; and
- Assistance paid out for individual assistance grants, emergency food and shelter, and other assistance to individuals.

Table 5-6 summarizes some costs associated with disaster recovery from just two significant storms in the past decade, including estimates of some costs that were covered by insurance (private wind coverage and federal flood insurance).

Table 5-6. Some Past Disaster Recovery Costs*

Hurricane Georges Damage As Of September 1, 1999	
Public Assistance (Infrastructure & Emergency Activities)	$ 54,257,290
Temporary Housing	$ 6,584,782
Individual Assistance	$ 3,966,572
Small Business Administration	$ 61,366,100
National Flood Insurance Program	$ 38,044,669
Wind Insurance (est.)	$131,000,000
TOTAL	$ 295,219,413
Tropical Storm Mitch Damage As Of September 1, 1999	
Public Assistance (Infrastructure & Emergency Activities)	$ 4,021,718
Temporary Housing	$ 754,845
Individual Assistance	$ 395,663
Small Business Administration	$ 5,678,700
National Flood Insurance Program	$ 51,527
TOTAL	$ 10,902,183

* Florida DCA, Recovery & Mitigation Section (pre-1999)

The Emergency Management Division of the Florida Department of Community Affairs coordinates and administers aspects of FEMA's Public Assistance Program. For three major disaster declarations that included Monroe County, Table 5-7 summarizes the amounts of public assistance received by eligible recipients, including Monroe County, the cities, and eligible non-profit organizations. The data were not available by category; thus, it is not feasible to examine the types of damage and expenditures that resulted in the expenditures which might reveal mitigation opportunities.

Table 5-7. FEMA Public Assistance Reimbursements for Recent Disasters (as of June 2005).*

	Amount of Reimbursements		
Recipient	Hurricane Georges DR#1249	Hurricane Mitch DR#1259	Hurricane Irene DR#1306
Monroe County	$26,618,853	$2,337,920	$602,420
City of Key West	11,586,282	0	$8,020,253
City of Marathon	0	0	0
City of Key Colony Beach	0	0	0
City of Layton	0	0	0
Islamorada Village of Islands	$1,201,225	$291,483	0
Monroe County Housing Authority	$162,065	0	$3,381
Monroe County Mosquito Control	$18,247	0	0
Monroe County School District	$5,718,562	$131,733	$55,322
Key West Housing Authority	$117,094	0	0
Utility Board of Key West	$6,055,656	0	$219,031
Marathon Volunteer Fire & Rescue	$2,678		
Florida Keys Electric Cooperative	$628,396	$260,512	$175,307
Florida Keys Aqueduct Authority	$601,763	0	0
Historic Florida Keys Foundation	$12,654	0	0
Key West Art & Historical Society	$16,562	0	0
Monroe Association for Retarded Citizens	$11,054	0	0
Florida Keys Children's Shelter	$1,286	0	0
Florida Keys Outreach	$2,500	0	0
Pigeon Key Foundation, Inc	$71,760	0	0
Venture Out at Cudjoe Cay	$256,603	0	0
	$53,083,227	$3,021,647	$9,075,714

* Source: Florida Department of Community Affairs, Emergency Management, Public Assistance

5.5 Impacts of Hurricanes

To improve understanding of hurricanes and their impacts, the Florida Department of Community Affairs developed "The Arbiter of Storms" (TAOS). TAOS is an integrated hazards model that provides higher resolution data than are produced by the National Hurricane Center's SLOSH model. The SLOSH model calculates storm surge for an area of coastline called a basin. TAOS, which makes more extensive use of satellite and digital terrain data, has a higher resolution. In addition to storm surge estimates, TAOS calculates estimates of wave height, maximum winds, inland flooding, debris and structural damage. Computer models are approximations and all predications of storm impacts and damage that are based on models include some degree of uncertainty.

In 1998, estimates of projected damage for various land use types in different storm scenarios developed through the TAOS model were provided by the Department of Community Affairs. The projections include the number of parcels by type, total improved value, and six storm scenarios (tropical storm and all categories of hurricane). Anticipated damage is included for floods, winds, and wave action.

5.5.1 Buildings

Property values throughout Monroe County have increased significantly in recent years. Figure 5-1 shows how the average and median sale prices of single family homes have changed since 1965. When the 1999 LMS was prepared, the average property value was $120,000; as of mid-2005, the average value had climbed to $281,000. Similar increases have been experienced in the values of other types of properties. The average sale prices of mobile homes on single lots have risen from about $100,000 to nearly $250,000; condominiums have gone from about $200,000 to about $450,000.

Exposure to Hurricane Wind*
Residential Property: $9.3 million
Commercial Property: $2.1 million

Annualized Losses from Hurricane Wind**
Residential Losses: $137 million
Commercial Losses: $31 million

Tables 3.3.6* & 3.5.2**
Florida State Hazard Mitigation Plan (2004)

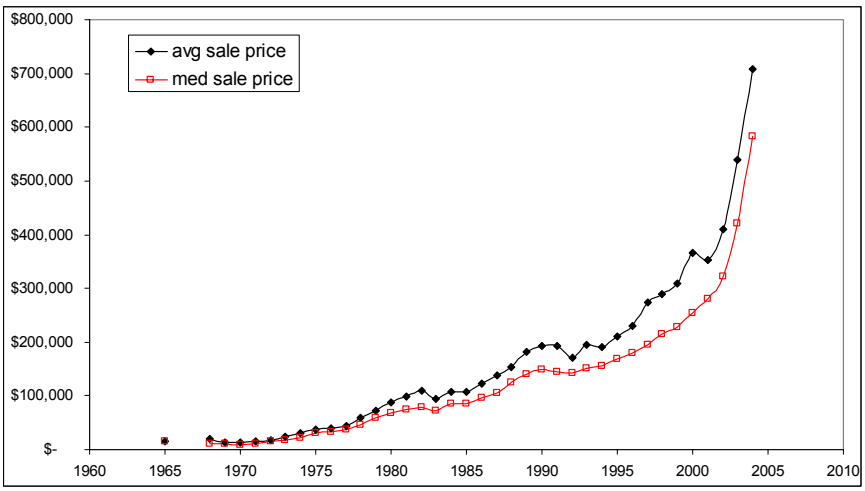

Figure 5-1. Single Family Home Values in Monroe County
(Monroe County Property Assessment Office)

The Monroe County Property Appraisal Office reports that there are 109 mobile home/recreational vehicle parks (land owned by park operator) and over 6,000 parcels of land are identified as "individual manufactured housing" lots. New mobile home parks have not been approved since 1987. Installation of new or replacement units must comply with current codes.

Three hundred sixty-six parcels of land are recorded as "hotel/motel" and it is estimated that there are over 8,900 available rooms (including guest houses). Most were built before current strict standards related to wind and flood hazards. Additions or substantial renovation will trigger the need to comply with current codes.

A need for affordable housing has been identified in the County and Municipal Comprehensive Plans and was underscored by the experiences in Hurricane Georges and Tropical Storm Mitch. Table 5-8 indicates the number of housing units that were determined to have been destroyed or to have sustained major or minimal damage.

Table 5-8. Monroe Housing Units Affected by Hurricane Georges & Tropical Storm Mitch

	Total Affected	Degree of Damage		
		Minimal	Major	Destroyed
Hurricane Georges	1,854	893	470	173
Tropical Storm Mitch	664	165	40	43

The TAOS information covers the entire county and does not provide separate data on the incorporated municipalities. Tables 5-9 through 5-15 summarize the damage projections for single-family homes, manufactured homes, multi-family homes, other residential buildings, commercial property, institutional property and hotels.

Although the TAOS projections were prepared for the 1999 LMS, the value of the results is not in the precision of the numbers, but in the order of magnitude or projected damage. For example:

- A category 3 hurricane is projected to result in some degree of damage to all occupancies, totally on the order of 50% of improved value.
- All single family homes will experience some degree of damage in all storms, with total structural damage approaching 100% in a Category 5 hurricane.
- All manufactured homes will be damaged to some degree in all storms, with total damage approaching 100% in a Category 3 hurricane.
- All multi-family residential buildings, other residential buildings, hotels, commercial buildings, and institutional buildings will be damaged to some degree in all storms, with total structural damage approaching 100% in a Category 5 hurricane.

Table 5-9. TAOS Damage Projections: Single-Family Homes (Total Parcels = 16,618; Improved Value = $3.01 billion, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	8,565	16,618	16,618	16,618	16,618	16,618
Damage ($000s)	Total Structure	243	686	1,066	1,571	2,248	2,946
	Structure Flood	100	245	413	620	848	1,128

Table 5-9. TAOS Damage Projections: Single-Family Homes
(Total Parcels = 16,618; Improved Value = $3.01 billion, 1998 dollars)

	Structure Wind	0	50	188	492	1,102	2,380
	Structure Wave	139	40	518	657	830	10,819
	Total Content	63	169	3,295	696	1,217	1,487

Table 5-10. TAOS Damage Projections: Manufactured Homes
(Total Parcels = 5,881; Improved Value = $308 million, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	5,881	5,881	5,881	5,881	5,881	5,881
Damage ($000s)	Total Structure	116	169	235	304	308	308
	Structure Flood	26	52	80	110	155	221
	Structure Wind	9	51	135	297	308	308
	Structure Wave	92	111	123	137	155	183
	Total Content	11	46	99	152	153	154

Table 5-11. TAOS Damage Projections: Multi-Family (<10)
(Total Parcels = 1,312; Improved Value = $250 million, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	522	1,312	1,312	1,312	1,312	1,312
Damage ($000s)	Total Structure	14	41	68	112	173	243
	Structure Flood	6	14	17	43	61	84
	Structure Wind	0	4	15	40	90	196
	Structure Wave	8	22	28	36	47	66
	Total Content	3	10	19	49	94	123

Table 5-12. TAOS Damage Projections: Other Residential
(Total Parcels = 7,652; Improved Value = $2.3 billion, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	5,629	7,652	7,652	7,652	7,652	7,652
Damage ($000s)	Total Structure	186	496	809	1,292	2,018	2,262
	Structure Flood	68	136	262	411	617	826
	Structure Wind	13	101	284	654	1,335	2,250
	Structure Wave	106	281	350	419	518	691
	Total Content	37	102	288	633	1,057	1,126

Table 5-13. TAOS Damage Projections: Commercial
(Total Parcels = 1,431; Improved Value = $409 million, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	1,287	1,431	1,431	1,431	1,431	1,431
Damage ($000s)	Total Structure	43	107	163	250	366	409
	Structure Flood	15	30	49	74	106	142
	Structure Wind	4	20	56	128	259	409
	Structure Wave	25	64	77	93	115	149
	Total Content	10	24	59	121	189	203

Table 5-14. TAOS Damage Projections: Institutional
(Total Parcels = 155; Improved Value = $80 million, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	142	155	155	155	155	155

Table 5-14. TAOS Damage Projections: Institutional
(Total Parcels = 155; Improved Value = $80 million, 1998 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
Damage ($000s)	Total Structure	5	17	28	45	70	80
	Structure Flood	1	4	74	12	18	26
	Structure Wind	1	4	11	25	51	80
	Structure Wave	4	9	11	15	18	24
	Total Content	0.5	2	9	22	36	40

Table 5-15. TAOS Damage Projections: Hotels
(Total Parcels = 215; Improved Value = $614 million, 1988 dollars)

		Tropical Storm	Hurricane Category				
			1	2	3	4	5
	Parcels Damaged	155	215	215	215	215	215
Damage ($000s)	Total Structure	22	72	170	320	563	614
	Structure Flood	5	9	54	97	147	201
	Structure Wind	6	30	85	195	396	614
	Structure Wave	11	35	40	49	63	90
	Total Content	3	7	57	158	294	306

5.5.2 Transportation Infrastructure

Historically, some areas and streets are more vulnerable than others to coastal flooding and/or pooling of rainfall runoff flooding from heavy rains. In the past decade, the following areas have been identified as likely to flood repetitively:

- MM 109 in the Upper Keys, which can hamper evacuation.
- MM 106, Lake Surprise area, vulnerable to the effects of wind driven wave run-up from E/NE and W/SW directions; heavy rainfall results in ponding.

- MM 111, the exposed beach area along the 18-mile stretch bordering Barnes Sound, experiences wave runup or "piling" with strong E and NE winds.
- MM 113, the Point Laura Marina Area, borders Barnes Sound is similarly susceptible to strong E and NE winds.
- MM 73.5 to approximately MM 74.5, the Lower Matecumbe area known as "Sea Oats Beach", vulnerable to NE / E / SE wind driven wave run-up.
- MM 30 -31, Big Pine Key. The area north of the Big Pine Plaza Shopping Center encompassing Wilder Road and Key Deer Boulevard, while not normally vulnerable to storm surge effects, experience rainfall ponding.
- MM 9-10, Big Coppitt Key, Bayside, experiences wind-generated wave run-up.

Transportation disruptions in the Keys occurred during evacuations for Hurricane Andrew and Hurricane Georges. Following Tropical Storm Mitch and Hurricane Georges, debris on U.S. 1 somewhat impeded traffic flow.

Both of the areas airports, Key West Airport and Marathon Airport, were closed before Hurricane Georges moved through the area. Damage to the airfield lighting at the Key West Airport closed the facility for five days. The Marathon Airport did not suffer any notable physical damage, but was closed for four days for debris removal and assessment and repair.

5.5.3 Communications

Most telephone service in the Keys is directed through facilities in Miami, although some local capability provides services within single exchanges. To ensure redundancy, two major trunk fibers are furnished from Homestead on the mainland to Key West (one buried and one aerial). However, most cable lines are located along the underside of fixed bridges, making them vulnerable if bridges fail. Installing sub-surface cable is not feasible because of rock substructure; environmental considerations inhibit underwater installations.

Communications infrastructure suffered in Hurricanes Andrew and Georges, downing towers and antennas in Dade County (cell towers, radio and TV towers, and repeaters) and damaging poles and switching equipment. The NOAA weather radio transmitter in Key Largo was damaged in Hurricane Andrew. Winds associated with Hurricane Georges destroyed the Key West Police Department's communication's tower. Major communication problems result from loss of electrical power.

5.5.4 Water Supply

Although Monroe County receives approximately 42 inches of rainfall per year, there are virtually no fresh water sources in the Upper Keys due to characteristics of the underlying limestone base rock. Some small fresh water lenses exist in the Lower Keys, primarily in Big Pine Key and Key West. Consequently, virtually all-potable water comes from the Biscayne Aquifer in Florida City via pipeline owned and operated by the Florida Keys Aqueduct Authority. The main pipeline that connects to the Upper Keys is laid underwater; some distribution pipelines are connected to roads and bridges and thus vulnerable to washout.

The Florida Keys Aqueduct Authority is an independent Special District created by the State of Florida Legislature, with the primary purpose and function to obtain, treat and distribute an adequate water supply to the residents and businesses of the Florida Keys. In 1998, the Florida Legislature modified the Authority's enabling Act to include providing wastewater collection, treatment and disposal throughout the unincorporated areas of Monroe County, with the exception of Key Largo. The Authority manages the infrastructure used to supply water and wastewater services to its customers in the Florida Keys, sets rates and provides customer service.

The Florida Key's Aqueduct Authority's mitigation and response activities include:

- The Authority's pipeline originates in Florida City in south Miami-Dade County. It ensures that the supply is protected from hazards and complies with South Florida Water Management Districts permit requirements, including identification and use of alternative sources. The Authority also operates and maintains two Reverse Osmosis emergency water treatment plants in the Florida Keys, to provide an alternate source when water cannot be supplied through the pipeline.
- The Authority participates in developing policies and procedures for responding to and recovering from shortages or disruptions in the supply and delivery of electricity, potable water, waste water collection and treatment and other fuels which affect or threaten to affect significant numbers of citizens and visitors.

The Authority, an agency of the State, has contingency plans and works diligently to provide water in the event of a hurricane in the Keys. Although not required to obtain local building permits, FKAA is required to meet or exceed the latest edition of the Florida Building Code when building or renovating its facilities. In addition, FKAA complies with the minimum design standards for flood protection of water and wastewater infrastructure and the

standards set by the Florida Department of Environmental Protection. Some redundancy for the regular supply line was provided by restoring two reverse osmosis plants: the Marathon facility would serve the Middle Keys and the Stock Island (Key West) facility would serve the Lower Keys. All primary pumping and water treatment facilities have backup power generation capability.

Hurricane Andrew: The water treatment plant in Florida City was damaged (lost roof on control room; roof on high service pump building; loss of Quonset hut; other minor building damage; partial loss of communication system). The only impact to customers was discontinuation of lime softening at the plant.

Hurricane Georges: The Florida Keys Aqueduct Authority reported that little, if any, disruption occurred in the transmission system during Hurricane Georges. Distribution system disruptions occurred in isolated areas due to broken water mains caused by uprooted trees. Wave action on the ocean side of the Spanish Harbor Bridge washed out a portion of the approach road and exposed about 250 feet of 24-inch transmission main (subsequently relocated to the roadway). As a private non-profit entity, FKAA was eligible to receive $1.69 million in federal disaster assistance. The assistance was used to rehabilitate damaged facilities.

All new or replaced pump stations are built above the estimate storm surge level of 14 feet above mean seal level. Other new structures are hardened to help withstand storm damage and protection operational capacity. An existing transmission station was retrofit with floodproofed doors.

Private water wells that draw from shallow freshwater sources can be contaminated by flooding, whether from storm surge or ponded runoff. A number were contaminated by floodwaters in Hurricane Georges, especially on Big Pine Key, where it appears that flooded septic tanks, cesspools and drain fields overflowed. After that event the South Florida Water Management District provided funding to the FKAA to install distribution mains to homes on Big Pine Key that had wells contaminated by the tidal surge. The project also supported environmental objectives related to the Key Deer, and endangered species, by reducing withdrawals from the fresh water lens.

5.5.5 Electric Power

Electric power is supplied by Florida Keys Electric Cooperative from the Upper Keys to Marathon, and by Key West City Electric System from Marathon to Key West. The two

agencies cooperate to provide the best service for the area. Both utilities purchase power from larger suppliers.

City Electric has the capability to generate electricity at its plant in Key West. The Electric Cooperative has limited generating capability at its Marathon Plant. With the exception of the private community of Ocean Reef in North Key Largo, the majority of electric lines in the county are above-ground. Due to vulnerability, power poles are not located on bridges but are submerged. Subsequent to Hurricane Andrew, some poles were re-designed to withstand higher wind forces. Both electric utilities have replaced older equipment with newer, more resilient designs and materials.

Hurricane Andrew: Due to the loss of the Florida Power and Light Company's electrical tie line in Dade County, Monroe County's approximately 78,000 residents were without power or on limited power for approximately two weeks. The Florida Keys Electric Cooperative reported a $130,000 loss of utility poles and related infrastructure. A report by the Florida Sea Grant Program identified lack of power as one the most significant factors affecting businesses and, while such damages were difficult to quantify in a monetary sense, they "left an indelible economic footprint on many businesses in the Keys."

Hurricane Georges: The Lower Keys experienced significant disruption of electric power. Damage to transformers, power poles, and transmission lines was responsible for widespread power outages, especially in areas serviced by Key West City Electric System. Power was restored on a priority basis with efforts directed at hospitals and critical services. Most electricity was reestablished within two weeks; however, as with most disasters, restoration in the hardest hit areas progressed more slowly. Power outages created major economic loss to Key businesses that are heavily dependent on the tourist trade. Disaster related unemployment, primarily due to the lack of electricity was significant because of loss of jobs in the service industry.

5.5.6 Wastewater Facilities

The State's Hurricane Georges assessment report noted that domestic wastewater facilities were surveyed in the two weeks following the storm. All regional facilities remained functional throughout the event, including facilities in Key West and Key Colony Beach. Approximately 250 package treatment plants are located throughout the County to serve such uses as motel, mobile home and RV parks, restaurants, and others. The loss of power to these small package plants did not result in overflows. While power was being restored,

to prevent health and safety problems sewage was hauled away from these small collection systems.

5.5.7 The Economy

Disruption of the local economy is an anticipated consequence of hurricanes that directly affect the Florida Keys. Although major storms may generate debris and cause building and infrastructure damage, the most detrimental short-term impact of large and small storms is caused by the loss of electric power. The most significant long-term impact would be caused by major damage to U.S. 1. Lengthy repairs and limited easy access to the Florida Keys would directly affect tourism and the flow of goods.

The Florida Keys are susceptible to economic disruption because the primary industries are related to retail sales, service, tourism, and fishing. Events that cause visitors to stay away would result in economic loss to local businesses and loss of tax income to local governments. The fishing industry would suffer economically with loss of power (affects ice production) and transportation disruption (affects transport to the mainland).

With a relatively high percentage of retirees in the area, interruption in government services that provide social security, disability, unemployment, and welfare payments would result in some economic impacts.

Major disasters can create a "domino effect" that can hurt the economy. For example, major damage and loss to residential properties can lead to displacement of people. Decrease in population means loss of clientele for local businesses. Businesses themselves may be destroyed or damaged to the degree that they cannot operate (whether short- or long-term). Even without initial major population relocation, business closings can contribute to reduced services, leading some to relocate in the short-term. Business closings and destruction or severe damage of facilities like schools, libraries, and other public buildings may eliminate jobs (even in the short-term) may lead some people to leave the area.

The Florida Keys Employment and Training Council has noted the significance of disasters on employee dislocation, unemployment, and underemployment. Because of the nature of the economy and the severe shortage of affordable housing, many employees do not have a stable economic base. Even a minor interruption in business may have serious effects on the work force. Given the already short supply of housing, another complicating factor is the likely reduction in the housing supply due to damage.

Both Hurricane Andrew and Hurricane Georges caused economic disruption in Monroe County, primarily due to the interruption of tourism. In addition, the fishing industry was hard hit due to the loss of many seafood traps, lack of ice for storage, and transportation disruption. Loss of power disrupted not only hospitality and retail businesses, but affected gas stations that could not pump and were slow to receive fuel because of transportation disruptions. The loss of more than 80 channel markers throughout the Keys curtailed boating and caused the suspension of cruise ship visits. In addition, the County and municipal governments were affected by a reduction in sales, infrastructure, and bed tax revenues immediately after the storm, resulting from business slow-downs

5.5.8 Environmental Resources

After Hurricane Andrew in 1992, the Monroe County Cooperative Extension Service received a grant to study environmental consequences. The study, "The Effect of Hurricane Andrew on Monroe County's Natural Resources and Its Dependent Industries," identified natural resources affected by the hurricane. It states that impacted resources include "pine rocklands, hard wood hammocks, mangrove forests, cypress domes, the freshwater regimes of the sawgrass community, and the coral reefs offshore of Key Largo."

The study notes that although South Florida ecosystems have evolved to adapt to natural episodic massive disturbances, including hurricanes, droughts, wildfires, and freezes, the growth of urban environments has significantly altered the ecology and ability of the ecosystems to respond and recover from catastrophic events.

Mangroves are very important to the environment of the Keys and serve as protective buffers in storms. Hurricane Andrew damaged the mangroves in Everglades National Park as severely as 80-95% in places, although areas south of the hurricanes' eye experienced more limited defoliation and branch damage. The study demonstrated that trees continue to suffer after the passage of a storm; initial estimates of mortality eventually were increased by up to 50%. Delayed mortality has been observed following past hurricanes, sometimes up to 2 years after the initial event.

Marsh Communities appeared to have survived Hurricane Andrew with little apparent damage, although the loss of periphyton, (which fish feed on) could affect "fish abundances." Pineland damage had a positive influence because of increased sapling growth. Hardwood hammocks are more susceptible to wind damage than pines. In North Key Largo, Hurricane Andrew damaged about two-thirds of the upland hardwood hammock trees.

Because Hurricane Andrew came ashore north of Monroe County, the Florida Keys reefs, including those in the Key Largo National Marine Sanctuary, were spared the affects of hurricane force conditions. Hurricanes can cause major damage to coral reefs; in past surveys in Puerto Rico, it was found that major hurricanes leave behind considerable breaks in coral formations.

Hurricanes can have a variety of impacts on fishery resources, including short-term and long-term impacts that are detected only after extended monitoring. After Hurricane Andrew, three species appeared to experience harvest declines in 1992 and 1993: Spanish Mackerel, Dolphin, and Spiny Lobster. In addition, there was a consistent decline in shrimp following the storm, but catches increased in the following year.

A survey of the commercial fishing industry after Hurricane Andrew, found that 53% of 43 survey respondents reported adverse impacts, primarily in the lobster industry because the storm occurred during the lobster season. The industry experienced inventory loss (virtually all 1 million traps were in the water), disruption of utilities (electric power to make ice), communications (for sales transactions), and transportation.

Overall, hurricanes are necessary and natural occurrences for the historical maintenance of the natural environment of the Florida Keys. Although Hurricane Andrew caused a relatively minor disruption of the portion of Monroe County's economy that is based on natural resources, the event pointed out opportunities to mitigate the impacts on the industry. In particular, restoration of power is a high priority.

5.5.9 Historic Resources

In recent years, properties and sites that are listed on the National Register of Historic Places have not sustained major damage due to hurricanes. The Old Monroe County Courthouse, a state-owned building, has suffered wind damage in the past. It was retrofit with window protection using FEMA's Hazard Mitigation Grant Program funds. FEMA's funds also were used to retrofit the steeple of the Old Key West City Hall with motorized hurricane shutters.